5. MAJOR ACTIVITIES

In the previous section, we provided a snapshot of the activities we pursue in the Laboratory for Atmospheres. Let's have a closer look. This section presents a more complete picture of our work in measurements, data sets, data analysis, and modeling. In addition, we'll discuss the Laboratory's support for the National Oceanic Atmospheric Administration's (NOAA) remote sensing requirements. Section 5 concludes with a listing of our project scientists, a description of our interactions with other scientific groups, and an overview of our efforts toward commercialization and technology transfer.

Measurements

Studies of the atmospheres of our solar system's planets—including our own—require a comprehensive set of observations, relying on instruments on spacecraft, aircraft, balloons, and on the ground. All instrument systems provide information leading to a basic understanding of the relationship between atmospheric systems and processes, serve as calibration references for satellite instrument validation, or perform both functions.

Many of the Laboratory's activities involve developing concepts and designs for instrument systems for spaceflight missions, and for balloon-, aircraft-, and ground-based observations, as well. Balloon and airborne platforms let us view such atmospheric processes as precipitation and cloud systems from a high-altitude vantage point but still within the atmosphere. Such platforms serve as a step in the development of spaceborne instruments.

Table II shows the principal instruments that have been built in the Laboratory or for which a Laboratory scientist has had responsibility as Instrument Scientist. The instruments are grouped according to the scientific discipline each supports. Table II also indicates each instrument's deployment—in space, on aircraft or balloons, or on the ground. Further information on each instrument appears on the pages following Table II.

Table II: Principal Instruments Supporting Scientific Disciplines in the Laboratory for Atmospheres

	Atmospheric Structure and Dynamics	Atmospheric Chemistry	Clouds and Radiation	Planetary Atmospheres/ Solar Influences
Space		Total Ozone Mapping Spectrometer-Earth Probes (TOMS-EP) Shuttle Ozone Limb Sounding Experiment/ Limb Ozone Retrieval Experiment (SOLSE/ LORE) (Shuttle) Rayleigh Scattering Attitude Sensor (RSAS) (Shuttle) Triana/Earth Polchromatic Imaging Camera (EPIC)	Infrared Spectrometer Imaging Radiometer (ISIR) (Shuttle)	Solar EUV Flux Monitor Cassini Gas Chromatograph/Mass Spectrometer (GCMS) Cassini Ion and Neutral Mass Spectrometer (INMS) NOZOMI Neutral Mass Spectrometer (NMS) Neutral Gas and Ion Mass Spectrometer (NGIMS) CONTOUR Mission
Aircraft	Large Aperture Scanning Airborne Lidar (LASAL) ER-2 Doppler Radar (EDOP) Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE)	Airborne Raman Lidar (ARL) (DC-8) GSFC Airborne Ozone, Temperature and Aerosol Lidar	Cloud Lidar System (CLS) Leonardo Airborne Simulator (LAS)	
Ground/ Laboratory	Scanning Raman Lidar (SRL) Direct Detection Doppler Wind Lidar (edge technique) Lightweight Rain Radiometer - IIP Lidar Atmospheric Raman Spectrometer (LARS) - IIP	Stratospheric Ozone Lidar Trailer Experiment (STROZ LITE) Tropospheric Ozone Lidar Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA) - IIP	Micro Pulse Lidar (MPL) cloud THickness from Offbeam Returns (THOR) Lidar Scanning Microwave Radiometer (SMiR) COmpact Vis IR (COVIR) - IIP	

Spacecraft-Based Instruments (launch dates are in parentheses)

The ***Total Ozone Mapping Spectrometer (TOMS)*** on Earth Probe has provided daily mapping and long-term trend determination of total ozone, surface UV radiation, volcanic SO2, and UV-absorbing aerosols. (1996) For more information, contact Richard McPeters (Richard.D.McPeters.1@gsfc.nasa.gov).

The ***Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE)*** measured ozone profiles from the stratosphere down to the tropopause with high vertical resolution in 1997. SOLSE is a grating spectrometer that measured ozone in the upper stratosphere, while LORE is a filter radiometer that measured ozone in the lower stratosphere. The instruments are being reconfigured to more simulate the performance expected from the Ozone Mapper and Profiler System (OMPS). A reflight is planned in 2001 which will be an important risk mitigation activity for the National Polar Orbiting Environmental Satellite System (NPOESS) ozone instrument. For more information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov).

The ***Raleigh Scattering Attitude Sensor (RSAS)*** is a new low cost technique for determining spacecraft attitude. The hardware and theoretical basis were developed in the Laboratory and a patent is pending. The concept was flown twice on the Shuttle which demonstrated an ability to determine attitude to better than 0.01 degree. The concept has been proposed for chemistry missions in response to NASA AO's and will be employed in OMPS. A development is now underway, supported by the GSFC Commercial Utilization Office, to design a system for commercial application. For more information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov).

Triana/Earth Polychromatic Imaging Camera (EPIC): EPIC is a 10-channel spectroradiometer spanning the ultraviolet (UV) to the near-Infrared (IR) wavelength range (317.5 to 905 nm). The main quantities measured are 1) Column Ozone, 2) Aerosols (dust, smoke, volcanic ash, and sulfate pollution), 3) Sulfur Dioxide, 4) Precipitable Water, 5) Cloud Height, 6) Cloud Reflectivity, 7) Cloud Phase (ice or water), and 8) UV Radiation at the Earth's Surface. Other quantities related to vegetation, bi-directional reflectivity (hotspot analysis) and ocean color will also be analyzed. The two unique characteristics are 1) the first spaceborne measurements from sunrise to sunset of the entire sunlit Earth and 2) the first simultaneous measurements in both the UV and visible wavelengths. This will allow diurnal variations to be determined and permit extended measurements of aerosol characteristics. For more information, contact Jay Herman (Jay.R.Herman.1@gsfc.nasa.gov).

The ***Infrared Spectrometer Imaging Radiometer (ISIR)*** for the Space Shuttle will improve infrared techniques and technology for observing Earth's clouds and surface from the Space Shuttle in combination with microwave and active optical imaging. ISIR is based on smaller and more reliable IR imaging using uncooled detectors. (1997) For more information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The ***Solar EUV Flux Monitor*** measures the integrated solar Extreme Ultraviolet (EUV) and UV radiation above the Earth's atmosphere. The instrument uses a very small, spherical, windowless photodiode with grids to control the photoelectrons. (2000) For more information, contact Walter Hoegy (Walter.R.Hoegy.1@gsfc.nasa.gov).

The ***Gas Chromatograph/Mass Spectrometer (GCMS)*** for the Cassini Huygens Probe measured the chemical composition of gases and aerosols in the atmosphere of Titan. (1997) For more information, contact Hasso Niemann (Hasso.B.Niemann.1@gsfc.nasa.gov).

The ***Ion and Neutral Mass Spectrometer (INMS)*** on Cassini will determine the chemical composition of positive and negative ions and neutral species in the inner magnetosphere of Saturn and in the vicinity of its icy satellites. (1997) For more information, contact Hasso Niemann (Hasso.B.Niemann.1@gsfc.nasa.gov).

The ***NOZOMI Neutral Mass (NMS)*** Spectrometer on Planet-B will measure the composition of the neutral atmosphere of Mars to improve our knowledge and understanding of the energetics, dynamics, and evolution of the Martian atmosphere. The mass spectrometer will be flown on a spacecraft developed by the Japanese Institute of Space and Astronautical Science. (1998) For more information, contact Hasso Niemann (Hasso.B.Niemann.1@gsfc.nasa.gov).

The ***Neutral Gas and Ion Mass Spectrometer (NGIMS)*** on the CONTOUR Mission will provide detailed compositional data on both gas and dust in the near-nucleus environment at precisions comparable to those of Giotto or better. For more information, contact Paul Mahaffy (Paul.R.Mahaffy.1@gsfc.nasa.gov).

Aircraft-Based Instruments

The ***Large Aperture Scanning Airborne Lidar (LASAL)*** measures atmospheric backscatter with an emphasis on boundary-layer height and structure. Capable of (raster) scanning at up to 90 degrees per second, it provides a three-dimensional view of the aerosol structure of the lower troposphere and boundary layer. For more information, contact Stephen Palm (Stephen.P.Palm.1@gsfc.nasa.gov).

The ***ER-2 Doppler Radar (EDOP)*** measures the vertical rain and wind structure of precipitation systems to improve our understanding of mesoscale convective system structure. The data are also used to validate spaceborne rain measurement algorithms. For more information, contact Gerald Heymsfield (Gerald.M.Heymsfield.1@gsfc.nasa.gov).

The ***Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE)*** measures cloud and aerosol laser backscatter in 4 dimensions with high spatial and temporal resolution. Utilizing a unique conical scanning holographic telescope, this compact high performance lidar fits into most low to medium altitude aircraft as well as in a portable ground-based environmental housing for relatively low cost field experiment deployments. For further information contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

The ***Airborne Raman Lidar (ARL)*** measures the structure and concentration of methane and water vapor in the troposphere and lower stratosphere to further understand the chemistry of this region. For more information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The GSFC ***Airborne Ozone, Temperature and Aerosol Lidar*** is a two wavelength lidar system (308 nm and 355 nm) that detects two elastically scattered wavelengths and N2-Raman scattered radiation at 332 nm and 387 nm. The system uses 20 data channels spread over the four detected wavelengths. The instrument has been integrated on board the DC-8 for the SOLVE campaign. Colleagues at Langley contributed data channels for depolarization measurements at 532 nm and channels for aerosol backscatter at 1064 nm. Data products are aerosol backscatter and vertical profiles of ozone and temperature. For more information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Cloud Lidar System (CLS)*** measures cloud and aerosol structure from the high altitude ER-2 aircraft, in combination with multispectral visible, microwave, and infrared imaging radiometers. The instrument operates at 1064, 532, and 355 nm wavelengths and a repetition rate of 5 Khz. The data are used in radiation and remote sensing studies. For more information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The ***Leonardo Airborne Simulator (LAS)*** is an imaging spectrometer (hyperspectral) with moderate spectral resolutions. LAS will measure reflected solar radiation to retrieve atmospheric properties such as column water vapor amount, aerosol loadings, cloud properties, and surface characteristics. This instrument is currently under development and will be deployed aboard NASA ER-2 during the Southern Africa Fire-Atmosphere Research Initiative (SAFARI) campaign. For more information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

Ground-Based and Laboratory Instruments

The ***Scanning Raman Lidar (SRL)*** measures light scattered by water vapor, nitrogen, oxygen, and aerosols to determine the water vapor mixing ratio, aerosol backscattering, and aerosol extinction, as well as their structure in the troposphere. These trailer-based measurements are important for studying radiative transfer, convection, and the hydrological cycle. They are also useful for assessing the water and aerosol measurement capabilities of surface-, aircraft-, and satellite-based instruments. For more information, contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

Direct Detection Doppler Wind Lidar measures vertical wind profile from the surface to 12 km and 35 km, using the double-edge technique. Doppler measurements are derived from aerosol and molecular backscatter at 1064 nm and 355 nm. For more information, contact Bruce Gentry (Bruce.M.Gentry.1@gsfc.nasa.gov).

The small, ***Lightweight Rain Radiometer*** is a Laboratory development under the Instrument Incubator Program (IIP). The radiometer will employ a thinned array synthetic antenna at 10.7 GHz for future measurements from space. The instrument will provide global high-temporal-resolution precipitation measurements from a constellation of small satellites. For more information, contact Christian Kummerow (Christian.D.Kummerow.1@gsfc.nasa.gov).

The ***Lidar Atmospheric Raman Spectrometer (LARS)*** is currently being developed under NASA's Instrument Incubator Program in collaboration with Code 924. It will address a large number of high priority atmospheric science measurement requirements, including water vapor, aerosol scattering, extinction and optical depth, temperature, cloud liquid water and drop size, and cloud top and bottom heights. A broad band spectrometer will permit full spectral tuning across the entire Raman band. This capability will allow us to attempt other experimental measurements such as cloud droplet temperature. For further information contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

The ***Stratosphere Ozone Lidar Trailer Experiment (STROZ LITE)*** measures vertical profiles of ozone, aerosols, and temperature. The system collects elastically and Raman-scattered returns using DIfferential Absorption Lidar (DIAL). For more information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Tropospheric Ozone Lidar*** measures tropospheric ozone at wavelengths that have a large ozone absorption cross section. The system provides validation data for research and development programs aimed at monitoring tropospheric ozone from space. For more information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA)*** instrument is in development under the Instrument Incubator Program (IIP). The primary objective is high-resolution measurement of NO2, SO2, aerosol, and other cloud components. The core design is a wide field-of-view (FOV) front-end telescope that illuminates a filter/focal plane array (FFPA) package. For more information, contact Scott Janz (Scott.J.Janz.1@gsfc.nasa.gov).

Micro Pulse Lidar (MPL) makes quantitative measurements of clouds and aerosols. MPL is a unique "eye-safe" lidar system that operates continuously (24 hours a day) in an autonomous fashion. Thirty instruments are currently deployed. For more information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The cloud ***THickness from Offbeam Returns (THOR) Lidar*** will determine the physical and optical thickness of dense cloud layers from the cloud Green's function, which is the halo of diffuse light up to 0.5 km from the entry point of a lidar beam incident on the cloud layer. Lidar returns at these wide angles are stronger for thicker clouds and are relatively insensitive to cloud microphysics. (2001). For more information, contact Robert Cahalan (Robert.F.Cahalan.1@gsfc.nasa.gov).

The ***Scanning Microwave Radiometer (SMiR)*** will measure the column amounts of water vapor and cloud liquid water using discrete microwave frequencies. This instrument will be deployed with the upcoming series of SAFARI campaigns. For more information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

COmpact Vis IR (COVIR) is a Laboratory test model of an imaging radiometer for small satellite missions. The instrument is being developed under the Instrument Incubator program (IIP) and will measure visible and IR wavelengths in the following ranges: 10.3-11.3 µm, 11.5-12.5 µm, 9.5-10.5 µm, and 0.67-0.68 µm. The system employs uncooled microbolometer focal plane detectors. For more information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

Field Campaigns

Field campaigns typically use the resources of NASA, other agencies, and other countries to carry out scientific experiments or to conduct environmental impact assessments from bases throughout the world. Research aircraft, such as the NASA ER-2 and DC-8, serve as platforms from which remote sensing observations are made. Ground systems are also used for soundings and *in situ* measurements. In 1999, Laboratory personnel supported many such activities as scientific investigators or as mission participants in the planning and coordination phases. Field campaigns supported in this way include the following:

The Atmospheric Radiation Measurement Program (ARM) is a Department of Energy (DOE) program in which NASA participates. ARM is organized to study shortwave and longwave radiation, and cloud physics and dynamics. The program aims to determine how cloud structure is related to cloud albedo, transmission, and cloud absorption. ARM will also study the influence of all these factors on General Circulation Models (GCM). For more information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The ***Photochemical Activity and Ultraviolet Radiation Modulation Factors (PAUR II)*** campaign was a combined effort of European Union and invited NASA/GSFC scientists to simultaneously measure UV irradiance, aerosol optical depth, ozone, and aerosol plume height from Crete. GSFC's purpose was to compare ground-based estimates with those derived from the TOMS spacecraft instrument. The site was selected to study the influence of plumes of African dust that frequently pass over Crete during May. GSFC contributed an aerosol lidar, CIMEL sunphotometer, hand-held sunphotometer and ozone meter, and a UV-irradiance Ground-based Ultraviolet Radiometer (GUV) 100 meter. The data obtained has been shared with the entire PAUR team to put together a comprehensive study of the attenuation of UV radiation in the presence of clouds, ozone, and aerosols. For more information, contact Pawan K. Bhartia (Pawan.K.Bhartia.1@gsfc.nasa.gov).

The ***Network for the Detection of Stratospheric Change (NDSC)*** is an international program to determine changes in the physical and chemical state of the stratosphere, to obtain data to test and improve multidimensional stratospheric chemical and dynamical models, and to provide independent calibration of satellite instruments. For more information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

St***ratospheric Aerosol and Gas Experiment (SAGE) III Ozone Loss and Validation Experiment (SOLVE)*** is a measurement campaign designed to examine the processes controlling ozone levels at mid- to-high latitudes. Measurements made in the Arctic region in winter, conducted jointly with the European Commission-sponsored Third European Stratospheric Experiment on Ozone (THESEO 2000), will allow better prediction of ozone changes with changing climate and chlorine levels. For more information, see http://cloud1.arc.nasa.gov/solve/ or contact Paul Newman (Paul.A.Newman.1@gsfc.nasa.gov).

The ***Atmospheric Chemistry of Combustion Emissions Near the Tropopause (ACCENT)*** mission is an interagency mission to examine the effects of exhaust from rockets and aircraft in the upper troposphere and lower stratosphere. The results will show how the emissions interact with the background atmospheric gases, aerosol, and cloud particles and how the emissions may affect chemistry and climate. For more information, see http://hyperion.gsfc.nasa.gov/AEAP/FieldMissions.html or contact Don Anderson (Donald.E.Anderson.1@gsfc.nasa.gov).

South China Sea Monsoon Experiment (SCSMEX) is an international field experiment to study the water and energy cycles of the Asian monsoon regions. The purpose of the experiment is to better understand the key physical processes in the onset, maintenance, and variability of the monsoon over southeast Asia and southern China. This understanding is expected to lead to improved forecasts of the monsoon. For more information, contact William Lau (William.K.Lau.1@gsfc.nasa.gov).

The ***TRMM Field Campaigns (TRMM-LBA and KWAJEX)*** were carried out to validate the physical assumptions made by the TRMM satellite algorithms. The experiments included a broad spectrum of ground-based and airborne sensors designed to obtain in-situ observations of cloud structures and their evolutions. The improved knowledge of cloud constituents and dynamics is vital to gain confidence that the rainfall structure and latent heat release derived by the TRMM satellite are not only correct, but correct for the right reasons. For more information, contact Christian Kummerow (Christian.D.Kummerow.1@gsfc.nasa.gov).

Data Sets

In the previous discussion, we examined the array of instruments we use to gather weather and climate data. Once we have obtained the raw data from these instruments, we arrange the information into data sets useful for studying various atmospheric phenomena.

Televised Infrared Operational Satellite (TIROS) Operational Vertical Sounder Pathfinder

The Pathfinder Projects are joint NOAA/NASA efforts to produce multi-year climate data sets using measurements from instruments on operational satellites. One such satellite-based instrument suite is the TIROS Operational Vertical Sounder (TOVS).

TOVS is comprised of three atmospheric sounding instruments: the High Resolution Infrared Sounder-2 (HIRS-2), the Microwave Sounding Unit (MSU), and the Spectral Sensor Unit (SSU). These instruments have flown on the NOAA Operational Polar Orbiting Satellite since 1979. We have reprocessed TOVS data from 1979 to the present, using an algorithm developed in the Laboratory to infer temperature and other surface and atmospheric parameters from TOVS observations.

The data are used to study global and regional natural variability and trends and relationships between surface and atmospheric anomalies. Real time processing began in August 1997 to study the 1997 El Niño. For more information, contact Joel Susskind (joel.susskind.1@gsfc.nasa.gov).

Tropospheric Ozone Data

Tropospheric column ozone (TCO) and stratospheric column ozone (SCO) gridded data in the tropics for 1979-present are now available from NASA Goddard Space Flight Center via either direct ftp, world-wide-web, or electronic mail. Until recently the primary method to derive TCO and SCO from satellite data was by combining TOMS and SAGE ozone measurements. At NASA Goddard, monthly averaged TCO and SCO data are derived in the tropics for January 1979-present using the convective cloud differential (CCD) method [Ziemke et al., 1998; J. Geophys. Res., 22115-22127]. Further details regarding methodology and new adjustments made for aerosol contamination are discussed in Ziemke et al. [Bull. Amer. Meteorol. Soc., in press, March, 2000]. These data have been recently used in several published studies within Code 916 to characterize tropospheric ozone variabilities from monthly to decadal time scales. The CCD TCO and SCO data may be obtained via World Wide Web (http://hyperion.gsfc.nasa.gov/Data_services/Data.html). For more information contact Sushil Chandra (sushil.chandra.1@gsfc.nasa.gov).

Aerosol Products from the Total Ozone Mapping Spectrometer

Laboratory scientists are generating a unique new data set of atmospheric aerosols by reanalyzing the 17-year data record of Earth's ultraviolet albedo as measured by the TOMS. Laboratory staff developed the technique for extracting aerosol information from ultraviolet in 1996. This technique differs from others in that the UV measurements can reliably separate UV absorbing aerosols (such as desert dust and smoke from biomass burning) from non-absorbing aerosols (such as sulfates, sea-salt, and ground-level fog). In addition, the UV technique can measure aerosols over land and can detect some types of aerosols over snow/ice and clouds.

TOMS aerosol data are currently available in the form of an (uncalibrated) index, which, nevertheless, is providing excellent information about sources, transport, and seasonal variation of a variety of aerosol types. Work is currently in progress to relate the index to aerosol optical thickness and single-scatter albedo. For more information, contact Jay Herman (Jay.R.Herman.1@gsfc.nasa.gov).

Multiyear Global Surface Wind Velocity Data Set

The Special Sensor Microwave Imagers (SSM/I) aboard three Defense Meteorological Satellite Program (DMSP) satellites have provided a large dataset of surface wind speeds over the global oceans from July 1987 to the present. These data are characterized by high resolution, coverage, and accuracy, but their application has been limited by the lack of directional information. In an effort to extend the applicability of these data, the DAO developed methodology to assign directions to the SSM/I wind speeds and to produce analyses using these data. This methodology has been used to generate a 12.5-year dataset (from July 1987 through December 1999) of global SSM/I wind vectors. These data are currently being used in a variety of atmospheric and oceanic applications and are available to interested investigators. For more information, contact Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov).

Global Precipitation Data Set

An up-to-date, long, continuous record of global precipitation is vital to a wide variety of scientific activities. These include initializing and validating numerical weather prediction and climate models, providing input for hydrological and water cycle studies, supporting agricultural productivity studies, and diagnosing intra- and inter-annual climatic fluctuations on regional and global scales.

At the international level, the Global Energy and Water Cycle Experiment (GEWEX) component of the World Climate Research Programme (WCRP) established the Global Precipitation Climatology Project (GPCP) to develop such global data sets. Scientists working in the Laboratory have led the GPCP effort to merge microwave data from low-Earth-orbit satellites, infrared data from geostationary orbit satellites, and data from ground-based rain gauges to produce the best estimates of global precipitation.

Version 2 of the GPCP merged data set provides global, monthly precipitation estimates for the period January 1979 to the present. Updates are being produced on a quarterly basis. The release includes input fields, combination products, and error estimates for the rainfall estimates. The data set is archived at World Data Center A (located at the National Climatic Data Center in Asheville, NC), at the Goddard Distributed Active Archive Center (DAAC), and at the Global Precipitation Climatology Centre (located at the Deutscher Wetterdienst in Offenbach, Germany). Evaluation of this long-term data set in the context of the new TRMM observations is ongoing. Development of data sets with finer time resolution (daily and 3-hr) has been initiated. For more information, contact Robert Adler (Robert.F.Adler.1@gsfc.nasa.gov).

Data Analysis

Atmospheric Ozone Research

The Clean Air Act Amendment of 1977 assigned NASA major responsibility for studying the ozone layer.

Data from many ground-based, aircraft, and satellite missions are combined with meteorological data to understand the factors that influence the production and loss of atmospheric ozone. Analysis is conducted over different temporal and spatial scales, ranging from studies of transient filamentary structures that play a key role in mixing the chemical constituents of the atmosphere to investigations of global-scale features that evolve over decades.

The principal goal of these studies is to understand the complex coupling between natural phenomena, such as volcanic eruptions and atmospheric motions, and human-made pollutants, such as those generated by agricultural and industrial activities. These nonlinear couplings have been shown to be responsible for the development of the well-known Antarctic ozone hole.

With the anticipated growth in air travel in the next few years, another area of important research underway in the Laboratory is aimed at understanding the effects of aircraft emissions on the atmosphere's chemistry and physics. For more information, contact Pawan K. Bhartia (Pawan.K.Bhartia.1@gsfc.nasa.gov).

Total Column Ozone and Vertical Profile

Laboratory for Atmospheres scientists have been involved in measuring ozone since the late 1960s when a satellite instrument—the Backscatter Ultraviolet (BUV) Spectrometer—was launched on NASA's Nimbus-4 satellite to measure the column amount and vertical distribution of ozone. These measurements are continuing aboard several follow-on missions launched by NASA, NOAA, and, more recently, by the ESA.

An important activity in the Laboratory is developing a high-quality, long-term ozone record from these satellite sensors and comparing that record with ground-based and other satellite sensors. This effort—already more than a quarter century in duration—has produced ozone data sets that have played a key role in identifying the global loss of ozone due to certain human-made chemicals. This knowledge has contributed to international agreements to phase out these chemicals by the end of this century. For more information, contact Pawan K. Bhartia (Pawan.K.Bhartia.1@gsfc.nasa.gov).

Surface UV Flux

The primary reason for measuring atmospheric ozone is to understand how the UV flux at the surface might be changing and how this change might effect the biosphere.

The sensitivity of the surface UV flux to ozone changes can be calculated by using atmospheric models. Yet, until recently, we had no rigorous test of these models, particularly in the presence of aerosols and clouds. By comparing a multi-year data set of surface UV flux generated from TOMS data and high-quality ground-based measurements, we are increasingly able to quantify the respective roles of ozone, aerosols, and clouds in controlling the surface UV flux over the globe. For more information, contact Jay Herman (Jay.R.Herman.1@gsfc.nasa.gov).

Data Assimilation

The DAO in the Laboratory has taken on the challenge of providing to the research community a coherent, global, near-real-time picture of the evolving Earth system. The DAO is developing a state-of-the-art Data Assimilation System (DAS) to extract the usable information available from a vast number of observations of the Earth system's many components, including the atmosphere, the oceans, the Earth's land surfaces, the biosphere, and the cryosphere (ice sheets over land or sea).

The DAS is made of several components including an atmospheric prediction model, a variational physical space analysis scheme, and models to diagnose unobservable quantities. Each of these components requires intense research, development, and testing. Much attention must be given to insuring that the components interact properly with one another to produce meaningful, research-quality data sets for the Earth-system-science research community. (See also modeling section).

Observing System Simulation Experiments

Since the advent of meteorological satellites in the 1960s, considerable research effort has been directed toward designing space-borne meteorological sensors, developing optimum methods for using satellite soundings and winds, and assessing the influence of satellite data on weather prediction. Observing system simulation experiments (OSSE) have played an important role in this research. Such studies have helped in designing the global observing system, testing different methods of assimilating satellite data, and assessing the potential impact of satellite data on weather forecasting.

At the present time, OSSEs are being conducted to (1) provide a quantitative assessment of the potential impact of currently proposed space-based observing systems on global change research, (2) evaluate new methodology for assimilating specific observing systems, and (3) evaluate tradeoffs in the design and configuration of these observing systems. For more information, contact Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov).

Seasonal-to-Interannual Variability and Prediction

Climate research seeks to identify natural variability on seasonal, interannual, and interdecadal time scales, and to isolate the natural variability from the human-made global-change signal. Climate diagnostic studies use a combination of remote sensing data, historical climate data, model outputs, and assimilated data. Climate diagnostic studies will be combined with modeling studies to unravel physical processes underpinning seasonal-to-interannual variability. The key areas of research include the El Niño Southern Oscillation (ENSO), monsoon variability, interseasonal oscillation, and water vapor and cloud feedback processes. Several advanced analytical techniques are used, including wavelets, multivariate empirical orthogonal functions, singular value decomposition, and nonlinear system analysis.

The Laboratory is also involved in NASA's Seasonal-to-Interannual Prediction Project (NSIPP). This collaboration between NASA and outside scientists is developing a system to predict El Niño events by utilizing a combination of satellite and *in situ* data. NSIPP will also employ a high-resolution atmosphere-land data assimilation system that will capitalize on the host of new high-resolution satellite data. This capability will allow us to better characterize the local and remote physical processes that control regional climates and limit predictability.

Promoting the use of satellite data is a top priority. Important satellite-derived data sets include TOPEX/Poseidon and Jason-1 ocean topography, the Earth Radiation Budget Experiment (ERBE), the International Satellite Cloud Climatology (ISCCP), Advanced Very High Resolution Radiometer (AVHRR), SSM/I, QuikSCAT, MSU, and TOVS Pathfinder data. Data from TRMM and EOS Terra and EOS Aqua platforms will be used extensively, as they become available. For more information, contact William Lau (William.K.Lau.1@gsfc.nasa.gov).

Rain Measurements

Rain Estimation Techniques from Satellites

Rainfall information is a key element in studying the hydrologic cycle. A number of techniques have been developed to extract rainfall information from current and future spaceborne sensor data, including the TRMM satellite and the Advanced Microwave Scanning Radiometer (AMSR) on EOS Aqua.

The retrieval techniques belong to four categories: (1) physical/empirical relationships that exist between microwave measurements (active and passive) and rain rates; (2) a theoretical, multifrequency technique that relates the complete set of microwave brightness temperatures to rainfall rate at the surface; (3) an empirical relationship that exists between cloud thickness and rain rates, using TOVS sounding retrievals; and (4) an analysis technique that uses low-orbit microwave, geosynchronous infrared, and rain gauge information to provide a merged, global precipitation analysis.

The multifrequency technique (category 2) also provides information on the vertical structure of hydrometeors and on latent heating through the use of a cloud ensemble model. The approach has recently been extended to combine spaceborne radar data with passive microwave observations.

The satellite-based rainfall information has been used to study the global distribution of atmospheric latent heating, the impact of ENSO on global-scale and regional precipitation patterns, the climatological contribution of tropical cyclone rainfall, and the validation of global models. For more information, contact Robert Adler (Robert.F.Adler.1@gsfc.nasa.gov).

Rain Measurement Validation for the TRMM

The objective of the TRMM Ground Validation Program (GVP) is to provide reliable area- and time-averaged rainfall data from numerous representative tropical and subtropical sites world wide for comparison with TRMM satellite measurements. Rainfall measurements are made at Ground Validation (GV) sites equipped with weather radar, rain gauges, and disdrometers. A range of data products derived from measurements obtained at GV sites is available via the TRMM Science Data and Information System (TSDIS). The list of data products has been developed to cover a range of space and time scales that will adequately reflect the rainfall variability and sampling characteristics of the TRMM Observatory. With these products, the validity of TRMM measurements will be established with accuracies that meet mission requirements.

The emphasis of this activity is the advancement of rainfall estimation from ground-based radars to allow for the climatological validation of the satellite products. To accomplish this task, rain measurement research, precipitation physics, procedural techniques for radar calibration, false echo removal and software for the generation of standard products all have to be developed and improved in concert. This is an ongoing process with results eventually benefiting not just the TRMM validation effort, but ground-based rainfall estimates in general. For more information, contact Christian Kummerow (Christian.D.Kummerow.1@gsfc.nasa.gov).

Aerosols/Cloud Climate Interactions

Theoretical and observational studies are being carried out to analyze the optical properties of aerosols and their effectiveness as cloud condensation nuclei. These nuclei produce different drop size distributions in clouds, which, in turn, will affect the radiative balance of the atmosphere.

Algorithms are being developed to routinely derive aerosol loading optical properties and total precipitable water vapor data products from data to be obtained by the EOS-era Moderate Resolution Imaging Spectroradiometer (MODIS). These algorithms are based on Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), MODIS Airborne simulator, AVHRR, and Landsat Thematic Mapper (TM) data.

Laboratory scientists are actively involved in analyzing data recently obtained from national and international campaigns. These campaigns include Smoke Cloud And Radiation-Brazil (SCAR-B), the Subsonic aircraft: Contrails and Cloud Effects Special Study (SUCCESS), and the Tropospheric Aerosol Radiative Forcing Observational eXperiment (TARFOX). For more information, contact Yoram Kaufman (Yoram.J.Kaufman.1@gsfc.nasa.gov).

Hydrologic Processes and Radiation Studies

Laboratory scientists are developing methods to estimate atmospheric water and energy budgets. These methods include calculating the radiative effects of absorption, emission, and scattering by clouds, water vapor, aerosols, CO2, and other trace gases. The observational data include the ERBE radiation budgets, ISCCP clouds data, Geostationary Meteorological Satellite (GMS; Japan) radiances, National Center for Environmental Prediction (NCEP) sea surface temperature, and Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) observations. The models include the Goddard Earth Observing System (GEOS) GCM, the Goddard Cloud Ensemble model (GCE), and an ocean mixed layer model.

Laboratory scientists study the response of radiation budgets to changes in water vapor and clouds during El Niño events in the Pacific basin and during westerly wind-burst episodes in the western tropical Pacific warm pool. We also investigate the relative importance of large-scale dynamics and local thermodynamics on clouds and radiation budgets and modulating sea surface temperature. In addition, we assess the impacts of basin-scale sea surface temperature fluctuations such as the El Niño on regional climate variability over the Indo-Pacific region, North America, and South America. For more information, contact William Lau (William.K.Lau.1@gsfc.nasa.gov).

Earth Observing System Interdisciplinary Investigations

The overall goal of NASA's EOS Program is to determine the extent, causes, and regional consequences of global climate change. This major scientific challenge will be addressed by more than 20 instruments flown on a series of spacecraft over a period of at least 15 years. In addition to the scientific investigations to be carried out by the instrument scientists, the EOS program also supports various interdisciplinary science investigations. Interdisciplinary investigations, such as the two described below, are designed to improve understanding of the Earth as a system by developing and refining integrated models that will use observations from EOS instruments.

Stratospheric Chemistry and Dynamics

The goal of Laboratory investigations of stratospheric chemistry and dynamics is to separate natural from human-made changes in the Earth's atmosphere, to determine their effects on ozone, and to assess radiative and dynamical feedbacks. We do this by analyzing stratospheric chemical and dynamical observations from current satellites and from aircraft campaigns. Studies include examining the processes that produce the Antarctic ozone hole and understanding similar processes that are occurring in the northern polar regions. The investigation combines Upper Atmosphere Research Satellite (UARS) data, trajectory modeling, and TOMS observations. This work will continue as new instruments are deployed on aircraft and satellites by the United States and by other nations. For more information, contact Mark Schoeberl (Mark.R.Schoeberl.1@gsfc.nasa.gov).

Regional Land-Atmosphere Climate Simulation (RELACS)

An end-to-end RELACS system is being developed in the Laboratory. RELACS consists of four components: A nested mesoscale model (MM5), a coupled land surface model, a regional four-dimensional data assimilation (4DDA) component, and a general circulation component. The investigation will provide downscaling of large-scale climate forcings derived from GCM and from 4DDA.

The core component of RELACS is a MM5 derived from the National Center for Atmospheric Research (NCAR)/Pennsylvania State University.

The MM5 is a non-hydrostatic meso-alpha- (200-2000km) and meso-beta- (20-200 km) scale primitive equation model. MM5 is an excellent tool for studying the multi-scale dynamics associated with precipitation processes and their impact on regional hydrological cycles. Improved physics include microphysical processes, radiation, land-soil-vegetation, and ocean mixed-layer processes. These variables have been incorporated to produce realistic simulations of tropical-midlatitude precipitation systems and their relationship to the large-scale environment. Components of the physical package have been tested for various mesoscale convective systems, including monsoon depressions, supercloud clusters, and meso-scale convective complexes. In an effort to develop RELACS, the MM5 has been coupled with the Land Surface Model (LSM), the Parameterization for Land Atmosphere Cloud Exchange (PLACE) model. The MM5-LSM will be nested within the GEOS GCM over continental scale regions such as Southeast Asia, the continental United States, or the Amazon region.

This approach represents a new Laboratory effort geared toward regional climate data analysis and modeling studies, performed in response to the emphasis on regional climate assessment under the Earth Science strategic plan and the science priorities of the US Global Change Research Program (USGCRP). For more information, contact William Lau (William.K.Lau.1@gsfc.nasa.gov).

Effects of Aircraft on the Atmosphere

Atmospheric Effects of Aviation Project (AEAP)

The AEAP sponsors research to evaluate the impact current subsonic and proposed high-speed civil aircraft have on stratospheric and tropospheric ozone and climate. AEAP is funded by the Office of Aeronautics and Space Transportation Technology. The project operates in coordination with observational and theoretical programs in NASA's Earth Science Enterprise. Elements of this program include aircraft campaigns, modeling of photochemistry and transport, and modeling of cloud-radiation interactions. Recent aircraft campaigns will help us understand the declining summertime portion of the stratospheric ozone annual cycle.

Modeling within the AEAP is concentrated in the Global Modeling Initiative (GMI). The GMI is a multi-institutional effort that is assembling various contributed software modules to create a coupled chemical-transport model, with a shared code residing at Lawrence Livermore National Laboratory. All contributors analyze model output, including members of the Atmospheric Chemistry and Dynamics Branch. The model will be used for three-dimensional aircraft assessment calculations.

The Atmospheric Chemistry and Dynamics Branch also provides the project scientist and several principal investigators to the AEAP, which is managed by the Goddard Flight Projects Directorate, Code 400. For more information, contact Stephan Kawa (Stephan.R.Kawa.1@gsfc.nasa.gov).

Modeling

Coupled Atmosphere-Ocean-Land Models

To study climate variability and sensitivity, we must couple the atmospheric GCM with ocean and land-surface models. Much of the work in this area is conducted in collaboration with Goddard's Laboratory for Hydrospheric Processes, Code 970. The ocean models predict the global ocean circulation—including the sea surface temperature (SST)—when forced with atmospheric heat fluxes and wind stresses at the sea surface. Land-surface models are detailed representations of the primary hydrological processes, including evaporation; transpiration through plants; infiltration; runoff; accumulation, sublimation, and melt of snow and ice; and groundwater budgets.

One of the main objectives of coupled models is forecasting seasonal-to-interannual anomalies such as the El Niño phenomenon. Laboratory scientists are involved in NSIPP, recently established in Goddard's Laboratory for Hydrospheric Processes. NSIPP's main goal is to develop a system capable of assimilating hydrologic data and using that data with complex, coupled ocean-atmosphere models to predict tropical SST with lead times of 6-14 months. A second goal is to use the predicted SST in conjunction with coupled atmosphere-land models to predict changes in global weather patterns. For more information, contact Max Suarez (Max.J.Suarez.1@gsfc.nasa.gov).

Global Modeling and Data Assimilation

Development of the Data Assimilation System

The DAO currently uses the GEOS-3 DAS to support the EOS Terra Mission. The GEOS-3 DAS is a major upgrade of the GEOS-1 DAS used for the first NASA reanalysis. The GEOS-3 DAS provides data products at a higher horizontal resolution (1° longitude by 1° latitude) and employs a new Physical-space Statistical Analysis System (PSAS). Other improvements include an interactive Mosaic-based land surface model, a state-of-the-art moist turbulence scheme, an online estimation and correction procedure for systematic forecast errors, and assimilation of space-borne observations of marine surface winds and total precipitable water. In the next upgrade scheduled before the EOS Aqua launch, the GEOS-3 DAS will be capable of assimilating interactively retrieved TOVS and advanced sounder data and precipitation data from TRMM and SSM/I instruments.

For the EOS-Aqua and beyond, the DAO is developing a next-generation numerical model for climate prediction and data assimilation in collaboration with NCAR. In addition, DAO is developing advanced data assimilation techniques using a combination of Kalman filtering and four-dimensional variational approaches. These techniques will allow us to make better use of a synoptic observations. DAO is also developing flow-dependent covariance models to maximize the benefit of high spatial resolution of the observations and of the model. For more information, contact Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov).

Development of the Next-Generation Global Model

The DAO is collaborating with the NCAR to develop a unified global general circulation model for climate, numerical weather prediction, data assimilation, and chemical constituent transport applications. The prototype configuration consists of a finitevolume, flux-form semi-Lagrangian dynamic core developed at the DAO, and physical parameterizations and land surface schemes available through NCAR. The DAO dynamic core, which is a candidate for incorporation into the NCAR Community Climate Model version 4 (CCM4), has been shown to be highly accurate in conservation properties; it also eliminates several known deficiencies of the spectral representation of the dynamic core. For more information, contact Shian-Jiann Lin (Shian-Jiann.Lin.1@gsfc.nasa.gov).

Cloud and Mesoscale Modeling

The MM5 and the cloud resolving GCE are used in several cloud and mesoscale studies.

These studies include the investigations of the dynamic and thermodynamic processes associated with cyclones and frontal rainbands, surface (ocean, land, and soil) effects on atmospheric convection, cloud-chemistry interactions, tropical and midlatitude convective systems, and stratospheric-tropospheric interaction. Other applications include investigating the effects of assimilating satellite-derived water vapor and precipitation fields on tropical and extra-tropical regional-scale (i.e., hurricanes, and cyclones) weather simulations.

Other areas addressed with these models include tropical climate applications involving long-term integrations. These allow the study of air-sea and cloud-radiation interactions and their application to the cloud-radiation climate feedback mechanisms; and surface energy, radiation, diabatic heating and water budgets associated with tropical and mid-latitude weather systems.

Such models also are used to develop retrieval algorithms. For example, the GCE model is providing TRMM investigators with four-dimensional data sets for the developing and improving TRMM rainfall and latent heating retrieval algorithms. For more information, contact Wei-Kuo Tao (Wei-Kuo.Tao.1@gsfc.nasa.gov).

Physical Parameterization in Atmospheric GCM

The development of physical parameterization and sub-models of the physical climate system is an integral part of climate modeling activities. Laboratory scientists are actively involved in developing and improving physical parameterizations of the major radiative transfer and moisture processes in the atmosphere. Both areas are extremely important for better understanding the global water and energy cycles.

For atmospheric radiation, we are developing efficient, accurate, and modular longwave and shortwave radiation codes. The radiation codes allow efficient computation of climate sensitivities to water vapor, cloud microphysics, and optical properties. The codes also allow us to compute the global warming potentials of carbon dioxide and various trace gases.

For atmospheric hydrologic processes, we are developing a new prognostic cloud liquid water scheme, which includes representation of source and sink terms as well as horizontal and vertical advection. This scheme incorporates attributes from physically based cloud life cycles, including the effects of downdraft, full-cloud microphysics within convective towers and anvils, cloud-radiation interactions, cloud microphysics, and cloud inhomogeneity correction. We are testing both the radiation and the prognostic water schemes with *in situ* observations from the ARM and TOGA-COARE activities. For land-surface processes a new and improved snow physics package is being developed to better simulate the hydrologic cycle. For more information, contact William Lau (William.K.Lau.1@gsfc.nasa.gov).

Trace Gas Modeling

We have developed two- and three-dimensional models to understand the behavior of ozone and other atmospheric constituents. We use the two-dimensional models primarily to understand global scale features that evolve in response to both natural effects, such as variations in solar luminosity in ultraviolet, volcanic emissions, and human effects, such as changes in chlorofluorocarbons (CFCs), nitrogen oxides, and hydrocarbons. The three-dimensional models start with assimilated wind and other meteorological data generated by the DAO and apply chemistry and transport models to simulate short-term variations in ozone and other constituents seen in the measurements. Our goal is to improve our understanding of the complex chemical and dynamical processes that control the ozone layer.

The modeling effort has evolved in four directions: (1) *Lagrangian models* are closely coupled to the trajectory models of an air parcel. The Lagrangian modeling effort is primarily used to interpret aircraft and satellite chemical observations; (2) *Two-dimensional (2D) non-interactive models* have comprehensive chemistry routines, but use specified, parameterized dynamics. They are used both in data analysis and multidecadal chemical assessment studies, (3) *Two-dimensional interactive models* have interactive radiation and dynamics routines, and can study the dynamical impact of major chemical changes, (4) *Three-dimensional (3D) models* have a full chemistry package, and use the analyzed wind fields for transport.

We use trace gas data from sensors on the UARS and from various NASA-sponsored aircraft and ground-based campaigns to rigorously test models. The integrated effects of processes such as stratosphere troposphere exchange, not resolved in 2D and 3D models, are critical to the reliability of these models. For more information, contact Anne Douglass (Anne.R.Douglass.1@gsfc.nasa.gov).

Support for National Oceanic and Atmospheric Administration Operational Satellites

In the preceding pages, we examined The Laboratory for Atmosphere's work in measurements, data sets, data analysis, and modeling. In addition, Goddard supports NOAA's remote sensing requirements. Laboratory project scientists support the NOAA Polar Orbiting Environmental Satellite (POES) and the Geostationary Operational Environmental Satellite (GOES) Project Offices. Project scientists assure scientific integrity throughout mission definition, design, development, operations, and data analysis phases for each series of NOAA platforms. Laboratory scientists also support the NOAA SBUV/2 ozone measurement program. This program is now operational within the NOAA/National Environmental Satellite Data and Information Service (NESDIS). A series of SBUV/2 instruments fly on POES. Post-doctoral scientists work with the project scientists to support development of new and improved instrumentation and to perform research using NOAA's operational data.

Laboratory members are actively involved in the NPOESS Internal Government Studies (IGS) and support the Integrated Program Office (IPO) Joint Agency Requirements Group (JARG) activities.

Geostationary Operational Environmental Satellites

NASA GSFC project engineering and scientific personnel support NOAA for the GOES operational satellites. GOES supplies images and soundings to study atmospheric processes, such as moisture, winds, clouds, and surface conditions. In particular, GOES observations are used by climate analysts to monitor the diurnal variability of clouds and rainfall and to track the movement of water vapor in the upper troposphere. In addition to high quality imagery, the GOES satellites also carry an infrared multichannel radiometer that NOAA uses to make hourly soundings of atmospheric temperature and moisture profiles over the United States. These mesoscale soundings are improving NOAA's numerical forecasts of local weather. The GOES project scientist at Goddard provides free public access to real-time weather images for regions all over the western hemisphere via the World Wide Web (http://rsd.gsfc.nasa.gov/goes/). For more information, contact Dennis Chesters (Dennis.Chesters.1@gsfc.nasa.gov).

Polar Orbiting Environmental Satellites

Algorithms are being developed and optimized for the HIRS-3 and the Advanced Microwave Sounding Unit (AMSU) launched on NOAA K in 1998. Real time analysis will be carried out thereafter, as was done with HIRS2/MSU data. For more information, contact Joel Susskind (joel.susskind.1@gsfc.nasa.gov).

Solar Backscatter Ultraviolet

NASA has the responsibility to determine and monitor the pre-launch and post-launch calibration of the SBUV/2 instruments that are included in the payload of the NOAA polar-orbiting satellites. We further have the responsibility to continue the development of new algorithms to determine more accurately the concentration of ozone in the atmosphere.

We have recently applied an upgraded version 7 algorithm for the total column ozone product being produced from the SBUV/2 data. The algorithm is similar to that now being used to produce TOMS data. It goes further than the TOMS algorithm because the SBUV/2 has extra shorter wavelengths designed for determination of the profile of concentration of ozone with altitude. One of these wavelengths, 305.6 nm, provides a sensitive measure of total ozone at the equator, where the sun is directly overhead and the column ozone amount is low. We use these equatorial measurements at this so-called "D-pair" wavelength to stabilize any long-term drift in calibration. Another outcome of these studies was an evaluation of the non-linearity in the response of the photomultiplier tube and a determination of a hysteresis effect in the tube as measurements were made immediately after the instrument came into sunlight from the dark. These led to small corrections that have improved the quality of the data. For more information, contact Richard Stolarski (Richard.S.Stolarski.1@gsfc.nasa.gov).

National Polar Orbiting Environmental Satellite System

The first step in instrument selection for NPOESS was completed with Laboratory personnel participating on the Source Evaluation Board, acting as technical advisors. Laboratory personnel were involved in evaluating proposals for the OMPS (Ozone Mapper and Profiler System) and the Crosstrack Infrared Sounder (CrIS), which is a candidate to accompany an AMSU-like crosstrack microwave sounder. Collaboration with the IPO continues through the Operation Algorithm Teams (OAT), which will provide advice on operational algorithms and technical support on various aspects of the NPOESS instruments. In addition to providing an advisory role, members of the Laboratory are conducting internal studies to test potential technology and techniques for NPOESS instruments. For more information, contact Joel Susskind (joel.susskind.1@gsfc.nasa.gov).

For OMPS, Laboratory scientists continue to support the IPO through the Ozone Operational Algorithm Science Team, which conducts algorithm research and oversight of the OMPS developer. An algorithm to analyze SAGE III data when it operates in a limb scattering mode is being developed to simulate retrievals expected from the OMPS profiler. This work is an extension of the retrievals used for the SOLSE/LORE mission. The retrievals from this Shuttle mission demonstrated the feasibility of employing limb scattering to observe ozone profiles with high vertical resolution down to the tropopause. This research is enabled by the advanced UV and Visible (VIS) radiative transfer models developed in the Laboratory. Laboratory scientists also participate in the Instrument Product Teams to review all aspects of the OMPS instrument development. The IPO is supporting a reflight of SOLSE/LORE as a risk mitigation effort related to the OMPS. For more information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov).

CrIS is a high-spectral-resolution interferometer infrared sounder with capabilities similar to those of the Atmospheric Infrared Sounder (AIRS), which will fly with AMSU A and the Humidity Sounder Brazil (HSB) on the EOS Aqua platform, to be launched in December 2000. Scientific personnel have been involved in developing the AIRS Science Team algorithm to analyze the AIRS/AMSU/HSB data. These data will be used in a pseudo-operational mode by NOAA/NESDIS and NOAA/NCEP. Simulation studies were conducted for the IPO to compare the expected performance of AIRS/AMSU/HSB with that of CrIS, as a function of instrument noise, together with AMSU/HSB. The simulations will help in assessing the noise requirements for CrIS to meet the NASA sounding requirements for the NPOESS Preparatory Project (NPP) bridge mission in 2005. Trade studies are also being done for the Advanced Technology

Sounder (ATMS), which will accompany CrIS on the NPP mission and replace AMSU/HSB. For more information, contact Joel Susskind (joel.susskind.1@gsfc.nasa.gov).

Tropospheric wind measurements are the number one priority in the unaccommodated Environmental Data Records (EDR) identified in the NPOESS Integrated Operational Requirements Document (IORD-1). The Laboratory is using these requirements in developing the Edge Technique Wind Lidar System to measure tropospheric wind profiles on a global scale. The IPO is supporting the effort through their IGS program. For more information, contact Bruce Gentry (Bruce.M.Gentry.1@gsfc.nasa.gov).

The IPO is also supporting a Goddard design study of a visible and infrared imaging radiometer based on advanced-technology array detectors. The goal is an imaging radiometer smaller, less costly, and more capable than previous instruments. The program is developing an instrument based on advanced microbolometer array (MBA) warm thermal detectors. A prototype MBA-based instrument, the ISIR, flew as a Shuttle small attached payload in August 1997. Its performance as a space-borne imager will be assessed from this Shuttle mission. A design study is planned for an array detector-based, operational, polar-orbiting, visible and infrared imager for a low-Earth-orbiter, applying the results of the ground and flight performance testing of ISIR. For more information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The IPO supports the development of the Holographic Optical Telescope and Scanner (HOTS) which investigates the feasibility of using this technology for lidar applications on NPOESS, including, but not limited to, a direct detection (edge) wind lidar system. For more information, contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

Project Scientists

Space flight missions at NASA depend on cooperation between two upper-level managers, the project scientist and the project manager, who are the principal leaders of the project. The project scientist provides continuous scientific guidance to the project manager while simultaneously leading a science team and acting as the interface between the project and the scientific community at large.

Table III lists project and deputy project scientists for current missions.

Table III: Laboratory for Atmospheres Project and Deputy Project Scientists

PROJECT SCIENTISTS		DEPUTY PROJECT SCIENTISTS	
Name	**Project**	**Name**	**Project**
Pawan K. Bhartia	TOMS	Anne R. Douglass	UARS, EOS Aura
Dennis Chesters	GOES	Ernest Hilsenrath	EOS Aura
Jay Herman	Triana	Arthur Hou	TRMM
Yoram Kaufman	EOS Terra		
Christian Kummerow	TRMM		
Charles Jackman	UARS		
Mark Schoeberl	EOS Aura		
Joel Susskind	POES		
EOS VALIDATION SCIENTIST		**FIELD/AIRCRAFT CAMPAIGN CO-PROJECT/MISSION SCIENTISTS**	
Name	**Project**	**Name**	**Project**
David O'C. Starr	EOS	Donald Anderson	AEAP
		P. Newman, M. Schoeberl	SOLVE
		Anne Thompson	SONEX
		Si-Chee Tsay	SAFARI-2000
		James Spinhirne	INDOEX
		James Spinhirne	SPARCLE

Interactions with Other Scientific Groups

Interactions with the Academic Community

The Laboratory depends on collaboration with university scientists to achieve its goals. Such relationships make optimum use of government facilities and capabilities and those of academic institutions. These relationships also promote the education of new generations of scientists and engineers. Educational programs include summer programs for faculty and students, fellowships for graduate research, and associateships for postdoctoral studies. The Laboratory frequently supports workshops on a wide range of scientific topics of interest to the academic community, as shown in Appendix 5.

NASA and non-NASA scientists work together on NASA missions, experiments, and instrument and system development. Similarly, several Laboratory scientists work on programs residing at universities or other federal agencies.

The Laboratory routinely makes its facilities, large data sets, and software available to the outside community. The list of refereed publications, presented in Appendix 7, reflects our many scientific interactions with the outside community; 70% of the publications involve co-authors from institutions outside the Laboratory.

Prime examples of collaboration between the academic community and the Laboratory include these recently established cooperative agreements with universities:

- Earth System Science Interdisciplinary Center (ESSIC), with the University of Maryland, College Park;
- Joint Center for Earth Systems Technology (JCET), with the University of Maryland, Baltimore County;
- Joint Center for Geoscience (JCG), with the Massachusetts Institute of Technology;
- Joint Center for Observation System Science (JCOSS), with the Scripps Institution of Oceanography, University of California;
- Center for Earth-Atmosphere Studies (CEAS), with Colorado State University;
- Cooperative Center for Atmospheric Science and Technology (CCAST), with the University of Arizona; and
- Cooperative Institute for Atmospheric Research (CIFAR) with UCLA.

These joint centers have been organized to increase scientific interactions between the Earth Science Directorate at GSFC and the faculty and students at the participating universities.

University and other outside scientists visit the Laboratory for periods ranging from one day to as long as two years. (See Appendix 1 for list of recent visitors and Appendix 4 for seminars.) Some of these appointments are supported by Resident Research Associateships offered by the National Research Council (NRC) of the National Academy of Sciences; others, by the Visiting Scientists and Visiting Fellows Programs currently managed by the Universities Space Research Association (USRA). Visiting Scientists are appointed for up to two years and carry out research in pre-established areas. Visiting Fellows are appointed for up to one year and are free to carry out research projects of their own design. (See Appendix 3 for a list of NRC Research Associates, USRA Visiting Scientists, Visiting Fellows, and Associates of the Joint Institutes during 1999.)

Interactions with Other NASA Centers and Federal Laboratories

The Laboratory maintains strong, productive interactions with other NASA centers and federal laboratories.

Our ties with the other NASA centers broaden our knowledge base. They allow us to complement each other's strengths, thus increasing our competitiveness while minimizing duplication of effort. They also increase our ability to reach the agency's scientific objectives.

Our interactions with other federal laboratories enhance the value of research funded by NASA. These interactions are particularly strong in ozone and radiation research, data assimilation studies, water vapor and aerosol measurements, ground truth activities for satellite missions, and operational satellites.

Interactions with Foreign Agencies

The Laboratory has had several ongoing programs in cooperation with non-U.S. space agencies. These programs involve many of the Laboratory scientists.

Major efforts include the TRMM Mission with the Japanese National Space Development Agency (NASDA); the Huygens Probe GCMS, with the ESA (CNES); the TOMS Program, with NASDA and the Russian Scientific Research Institute of Electromechanics (NIIEM); the Neutral Mass Spectrometer (NMS) instrument, with the Japanese Institute of Space and Aeronautical Science (ISAS); and climate research with various institutes in Europe, South America, South Africa, and Asia.

Laboratory scientists interact with about twenty foreign agencies, about an equal number of foreign universities, and two foreign companies. The collaborations vary from extended visits for joint missions to brief visits for giving seminars or, perhaps, working on papers.

Commercialization and Technology Transfer

The Laboratory for Atmospheres fully supports government/industry partnerships, SBIR's and technology transfer activities. The Laboratory was extremely proactive, and a key contributor, to development of the partnering process now used within Goddard. Through this process, government Principal Investigator's (PI) can team with industry to produce credible and competitive proposals that satisfy the Competition In Contracting Act (CICA) requirements. The Laboratory used this process three times under the Earth Systems Science Pathfinder (ESSP) Program and will continue to use this process on all major mission proposals. The Laboratory has four instrument development activities funded through the NASA IIP. Industry and university Co-Investigator's (Co-I) are important contributors on each program. Laboratory scientists also serve as Co-I's on proposals led by industry. These practices will continue on future proposals.

Prior to the last ESSP call, the Laboratory organized a partnering seminar for industry. Prospective PI's from NASA centers and universities presented outlines of their proposals for the express purpose of inviting collaboration. Over 140 companies were represented. Partnering interviews were arranged between PI's and industry representatives; over 60 interviews took place.

Successful technology transfer has occurred on a number of programs in the past and new opportunities will become available in the future. Past examples include the micro-pulse Lidar and holographic optical scanner technology. Industry now develops and markets micro-pulse Lidar systems to an international community. Twenty units have been sold and deployed thus far. A licensing agreement with industry permits the use of government patented holographic technology for commercial application to topographic mapping. New research proposals involving technology development will have strong commercial partnerships wherever possible. The Laboratory hopes to devote at least 10% to 20% of its resources to joint activities with industry on a continuing basis.